Evaluation of Soil Aeration Status and Improvement Practices in Landscapes

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Trees in landscape plantings can be exposed to many forms of environmental stress. Soil conditions which inhibit root aeration and cause root oxygen stress frequently are cited as causes of tree decline in landscapes. As a result, landscape architects and arborists often prescribe soil treatments that are claimed to enhance root aeration and tree performance. However, there is very little research indicating whether these expensive, labor-intensive practices offer any short- or long-term benefit. Thus, the primary goal of this project was to examine various aeration-enhancement procedures and quantify their effects on soil oxygen diffusion rate (ODR). The information obtained through this research is intended to aid arborists, landscape architects, park services, and homeowners make informed decisions concerning soil aeration practices.

In the following sections, we describe both laboratory and field experiments that quantify the effects of backfills and coring procedures on soil aeration. Soil aeration is described in these experiments in terms of ODR, which measures the ability of oxygen to move through soil to a point of consumption (i.e., a respiring root). In a previous project, and early in this project, we found that the oxygen concentration in soil air could be high, even in locations where trees were declining. Soil ODR has given the most consistent correlation with soil conditions and tree vigor.

The influence of fill soil on ODR

The decline and death of established trees has often been observed following grade changes associated with construction or landscaping activities. When grade changes have involved the addition of fill soils over established tree roots, subsequent declines have been ascribed to reduced air entry into the root zone. However, there is very little data that quantifies the effect of soil fills on ODR within the original soil mass. We have studied this question using several approaches.

In laboratory experiments, we packed soil into 10-cm-dia. plexiglass cylinders to a height of 6 cm and a bulk density of 1.5 g/cm^3 (Fig. 1). The cylinders were open at the top and closed at the bottom, so oxygen could enter the soil only by downward diffusion. ODR probes were inserted into the soil and ODR readings were taken for several days to obtain baseline readings. After these initial readings were obtained, an additional 20 cm of soil was packed into the cylinders on top of the original soil without disturbing the microprobes. We continued to measure ODR in the original soil for an additional 6-7 days to determine if oxygen diffusion to the microprobes was impeded by the fill soil. In these experiments, we did not detect any significant reduction in ODR following the addition of fill soils.

Similar experiments were done in the field using two methods. In one series of experiments, an open end of a 51-cm-dia X 46-cm-long steel cylinder was pressed approximately 6 inches into a loamy soil. ODR probes were inserted to a depth of 10 cm into the soil near the center of the circular area defined by the cylinder. ODR readings were taken daily for

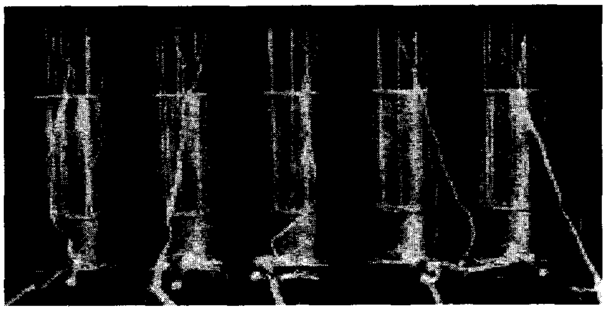

Fig. 1. Plexiglass cylinders used in laboratory experiments to assess the effects of fill soil and core-venting on soil ODR. As shown here, soil was initially added to a height of 6-10 cm. A weighed amount of soil was packed into a measured volume to obtain desired bulk densities. The small rods extending out of the top of the cylinders are the microelectrodes used to measure soil ODR. After several days of readings, additional soil was added to the containers to simulate backfill, and ODR was continuously monitored to detect changes. In other experiments, poorly-aerated soils were added to the cylinders and initial ODR readings obtained. Cores were then cut from the soil to determine if ventilation would improve ODR. Core vents were cut at distances ranging from 20 to 5 mm from ODR probes.

approximately 7 days, after which fill soil was added into the cylinder. Soil was added and hand-packed in layers until the height of the fill was approximately 30 cm above the original grade. The fill soil as added around the ODR probes so that they were not moved or disturbed. Daily ODR readings then were made for an additional 10 days. The results of these experiments were somewhat erratic. In one trial, we observed a sharp drop in ODR (from 0.5 to 0.25 ug/cm^2/min) after addition of the fill soil. However, in repeat trials, we could detect no significant change in ODR following addition of fill soil.

In a second series of field experiments, open box frames (1.2 M wide X 1.8 M long X 60 cm high) were constructed and set in place over a loamy soil (Fig. 2). Arrays of ODR probes and tensiometers were inserted in the soil near the centers of the boxes to a depth of 10 cm below the original grade. ODR readings were taken daily for approximately 7 days, after which 45 cm of fill soil was added to the boxes. In two boxes, the fill soil was the same loamy soil as that in the original grade. In two other boxes, however, the fill soil was a heavy clay. We continued to measure ODR daily, and detected no significant or consistent change following addition of fill soils. While somewhat surprising, these results are consistent with our measurements (conducted over several months) of ODR within a soil that had been overlaid with fill at a construction site (Fig. 3). While the fill soil itself was wet and had a consistently low ODR, the underlaying soil was drier (i.e., had more air-filled pore space) and had correspondingly higher ODRs.

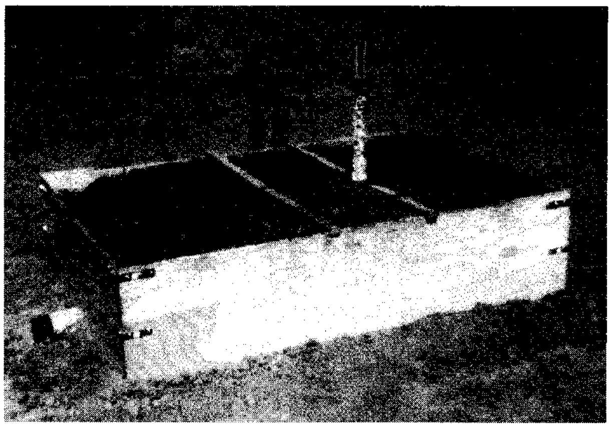

Fig. 2. Wooden box frames (l.2 M wide X 1.8 M long X 60 cm high) used in field experiments to test the effect of fill soil on ODR. The boxes were laid over a loam soil and arrays of ODR probes and tensiometers were inserted near the centers of the boxes extending to a depth of 10 cm below the original soil grade. ODR readings were taken daily for approximately 7 days before and after the boxes were filled with either a loam or a clay soil. In addition to measurements of ODR from within the box of fill soil, ODR was measured from an area alongside the box and unaffected by the fill.

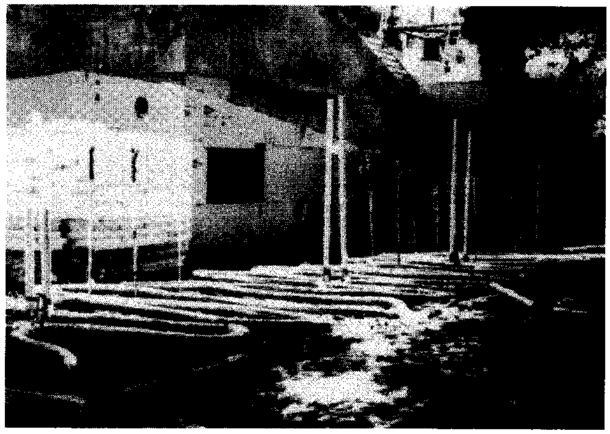

Fig. 3. A construction site illustrating a typical installation of aeration piping prior to addition of fill soil. At this site, established live oak trees are to the extreme right of the photograph. Approximately half of their root systems extend into the construction area. Construction design called for a sloping fill soil to extend from the wall of the structure (from the top of the insulation material) down to the edge of the asphalt walkway. We measured soil ODR at this site by pushing microelectrodes through the fill soil into the original grade. Electrodes were situated so that they were 1 to 6 inches from aeration pipes to detect gradients in oxygen status.

The influence of soil aeration enhancement procedures on ODR

We studied two common aeration enhancement procedures: 1) soil coring and 2) subsurface ventilation pipes. The effects of these practices on soil ODR were determined in a series of laboratory and field experiments.

In laboratory experiments, soil was packed to a depth of 10 cm in plastic cylinders as described above, and microelectrodes were installed in a circular array. After baseline ODR readings were obtained, small (5-7 mm dia) aeration holes were cut approximately 5 mm from each ODR probe. We continued to measure ODR for an additional 5-7 days after the coring process, but did not detect any significant changes. These experiments were repeated using larger (28 cm dia. X 32 cm high) cylinders into which

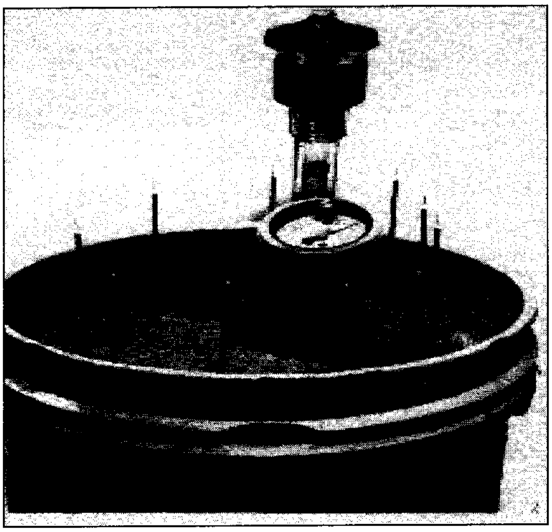

Fig. 4. Plastic cylindrical containers (28 cm dia. X 32 cm high) used to measure the effect of core venting on soil ODR. Weighed amounts of soil were added to the containers and packed to desired bulk densities. Soil moisture was measured by means of a tensiometer. Microelectrodes were placed in arc arrays on opposite sides of the containers and ODR measured for several days. Core vents were cut between the electrodes on one side of the container to allow aeration. ODR measurements were made for an additional 7-10 days to compare oxygen diffusion rates between aerated and non-aerated sides of the containers.

either a loam soil or a clay soil was added and packed to a bulk density of approximately 1.5 g/cm^3 (Fig. 4). In these experiments, arcs of microelectrodes were installed at opposite edges of the soil cylinders. After baseline ODR readings were obtained, 2.5-cm-dia. aeration holes were cut out of one side of the cylinder, with aeration holes interdigitated between the microelectrodes. This allowed us to compare, within the same soil mass, ODR values in an aerated and a non-aerated zone. This experiment was repeated in its entirety four times and, while aeration holes increased the variability in ODR readings, they did not appear to cause a consistent, significant increase in ODR (Fig. 5).

In field experiments, a 2 M length of 15-cm-dia. aeration tubing was laid on the surface of a loam soil with open ends extending outside the box frames described above (Fig. 2). Microelectrodes were installed to a depth of 10 cm below original grade in linear arrays perpendicular to the tube. Electrodes were 1 to 15 cm from the aeration tube. After fill soil was added and packed into place, ODR was measured as a function of distance from the aeration tube. We detected no difference (i.e. ODR was no greater near the tube than 15 cm away).

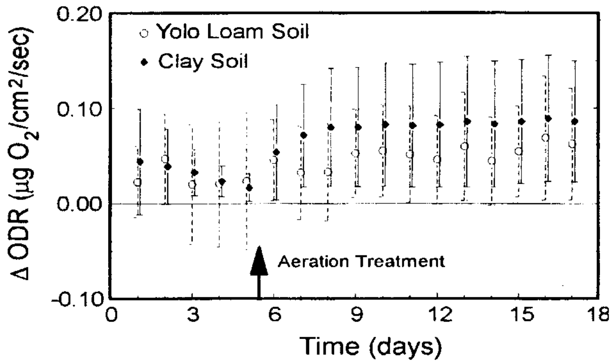

Fig. 5. The results of experiments conducted using the apparatus illustrated in Fig. 4. Each point represents the difference in ODR measurement between the aerated and non-aerated sides of the container (ODR aerated - ODR non-aerated), and is the mean from 4 separate experiments. The zero-reference line indicates where a ODR points would fall if there was no difference between aerated and non-aerated sides. Verticle lines indicate ±1SD aeration cores caused a slight (0.04-0.07), but insignificant relative increase in ODR.

Conclusions

Although grade changes frequently have been blamed for tree failures, and the mode of action has been described as "reduced root aeration", our results suggest that fill soils do not markedly reduce soil ODR. Furthermore, the procedures widely used to "enhance" soil aeration do not markedly increase soil ODR. These results suggest that either other mechanisms are involved in tree failures following grade changes, or that tree roots are able to sense very subtle changes in ODR that cannot be reliably measured.

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